USING DEEP LEARNING TO PREDICT DEMOGRAPHICS FROM MOBILE PHONE METADATA

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ABSTRACT

Mobile phone metadata are increasingly used to study human behavior at large-scale. There has recently been a growing interest in predicting demographic information from metadata. Previous approaches relied on hand-engineered features. We here apply, for the first time, deep learning methods to mobile phone metadata using a convolutional network. Our method provides high accuracy on both age and gender prediction. These results show great potential for deep learning approaches for prediction tasks using standard mobile phone metadata.

1 INTRODUCTION

Our mobile phones produce metadata every time we send or received a text or a phone call. These metadata – recording who calls or texts who, for how long, and from where – provide a detailed view of human behavior including mobility at large-scale. This data has great potential for good but often lacks basic demographic information, which is why there has recently been a growing interest in predicting demographic information, such as age and gender, from mobile phone metadata. Previous approaches relied on standard machine learning algorithms and hand-engineered features (Sarraute et al., 2014; Frias-Martinez et al., 2010).

Convolutional networks (ConvNets) have recently systematically outperformed existing approaches in analyses of large-scale image datasets (Krizhevsky et al., 2012; Simonyan & Zisserman, 2014). We show in this work how a ConvNet can be used to predict demographic information such as age and gender from standard mobile phone metadata.

2 TEMPORAL REPRESENTATION

We focus on using the temporal information contained in mobile phone metadata. We represent the data as 8 matrices summarizing mobile phone usage on a given week with hours of the day on the x-axis and the weekdays on the y-axis (see Figure 1). These 8 matrices are combined into a tensor (less formally, a 3-dimensional matrix) with a separate 'channel' for each of the 8 variables of interest. These 8 channels are the number of unique contacts, calls, texts and the total duration of calls for respectively incoming and outgoing interactions. We model each week separately.

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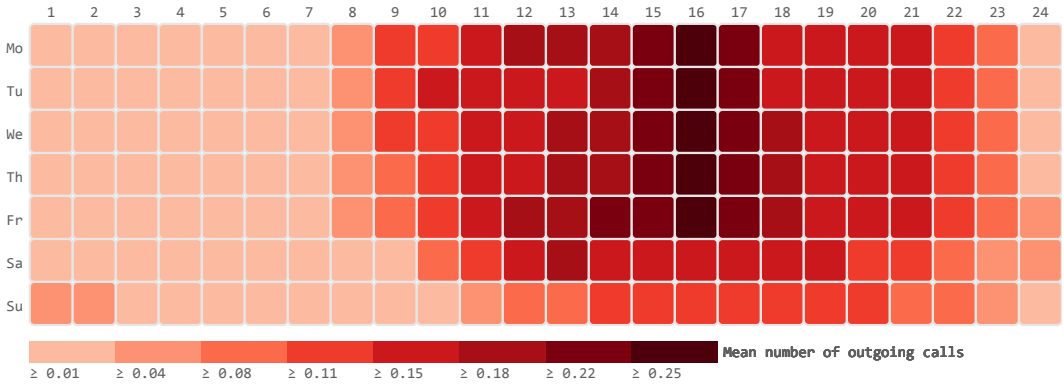

Figure 1: The mean number of outgoing calls, one of the channel our matrix representation uses, when averaged across the population.

3 CONVNET ARCHITECTURE

Choosing the right architecture of the ConvNet for the task at hand is crucial to reaching high accuracy for the prediction task. We use a series of 5 horizontal conv. layers followed by a vertical conv. filter and 2 dense layers (see Table 1) to capture increasingly abstract patterns.

Table 1: Architecture for the ConvNet. The leaky ReLU activation layers are not shown for brevity.

Layer Name	Conv. Filter Size
$Input$	-
$conv_1$	4x1
$conv_2$	4x1
$conv_3$	4x1
$conv_4$	4x1
$conv_5$	12x1
$conv_6$	1x7
$dense_7$	-
$dense_8$	-
$softmax_9$	-

The ConvNet performs a prediction of the demographic attribute on each week of data using the softmax layer. These predictions are traditionally averaged to generate a single prediction for the user. We find that using the ConvNet as a feature extractor with a support vector machine (SVM) for prediction increases accuracy by 1 to 3 percentage points (see Table 2).

4 RESULTS

We demonstrate the effectiveness of our method on gender and age prediction. Our results are based on anonymized call detail records (CDRs) for 150.000 people in a Western European country for 15 weeks. Table 2 shows that our method achieves a high accuracy on both age and gender prediction.

Table 2: Accuracy of classifiers when predicting age and gender.

	Age	Gender
Random	35.7%	56.3%
ConvNet	60.7%	78.3%
ConvNet-SVM	**63.1%**	**79.7%**

5 CONCLUSION

We here applied, for the first time, deep learning algorithms to prediction tasks using mobile phone metadata. Our method provides a high accuracy on both age and gender prediction. These results show the great potential of deep learning techniques for prediction tasks using mobile phone metadata.

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